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(54) Method and apparatus for ancillary data in a wavelength division multiplexed system

(57) This invention provides method and apparatus for communicating ancillary data in a wavelength division multiplexed (WDM) system. According to the invention, a low bit rate channel is provided over a amplitude modulated sub-carrier that is in turn used to amplitude modulate an optical data signal that is output from a transmitter in the network. Data carried by the

low bit rate channel can be used by another network element (NE) to determine the identity of the channel source, thereby allowing the NE to verify its connectivity to that source via the network. This invention is particularly useful in metropolitan optical networks (MON) where inexpensive methods of determining network connectivity are required.

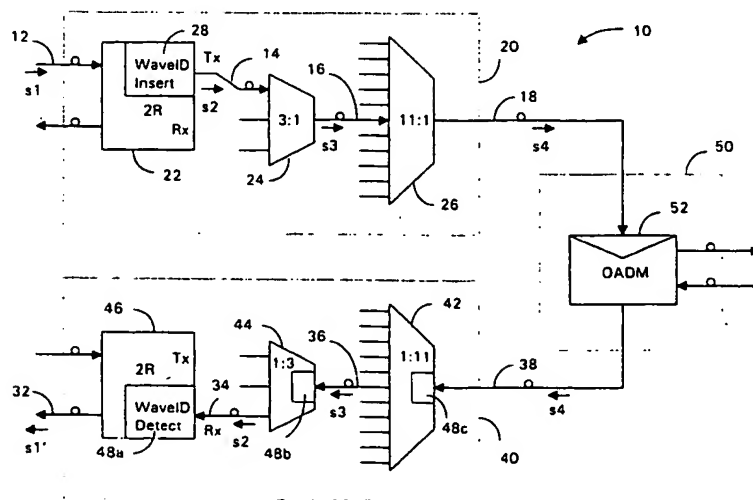


FIG. 1

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D scription**Field of the Invention**

[0001] This invention relates to wavelength division multiplexed (WDM) optical systems, and more particularly to method and apparatus for a dense WDM (DWDM) optical system.

Background of the Invention

[0002] In optical transmission systems the capability to determine the connectivity of network elements (NE) is important in performing equipment inventory management, fault isolation, and automated provisioning of the system. In a DWDM system, which typically carries 33 or more multiplexed channels of information over a single fiber, this capability would normally require an optical demultiplexer in each NE in order to access the information carried by the channels. This information would then be used to determine the connectivity of the NE. However, optical demultiplexers are relatively expensive components, and therefore, to include them in an NE solely for determining the connectivity of the NE where they otherwise would not be required is undesirable. It appears then, that an alternative technique of providing the capability to determine the connectivity of an NE would be useful.

Summary of the Invention

[0003] An object of the present invention is to provide improved method and apparatus for communicating ancillary data in a WDM optical transmission system.

[0004] The present invention provides a low bit rate data channel for carrying ancillary data between a channel wavelength source and an optical NE in a WDM system. The low bit rate data channel, hereinafter called a WaveID, is carried by a sub-carrier frequency signal that has been modulated by the ancillary data. The modulated sub-carrier frequency signal is used to modulate an optical data signal. The WaveID of each channel is orthogonal to other WaveIDs. That is, for an optical signal that is comprised of a plurality of modulated optical data signals that are each of a different channel wavelength, each WaveID can be detected independently from other WaveIDs.

[0005] According to one embodiment of the present invention each WaveID can carry ancillary data that includes channel source identification information, such as a unique channel identifier that uniquely identifies the wavelength source. Further to this end, the WaveID could carry such ancillary data as: Internet protocol (IP) address of the source, physical location identifier of the source, working or protection channel identification, payload format and bit rate identifiers, and other such information as dictated by future requirements.

[0006] The WaveIDs can be detected by an NE

equipped with a tap coupler, a photo detector, and a WaveID detector. By tapping an incoming optical signal and detecting the set of WaveIDs present, an NE can determine the wavelength sources to which it is connected via the network. This allows the NE to verify or discover its connectivity to the network. This capability is particularly attractive for Metro Optical Networks (MON) where inexpensive techniques of optical connectivity verification are required.

[0007] An advantage of the present invention is that it does not require optical demultiplexing of the channel wavelengths in order to identify the channel wavelength sources. Consequently, adding optical demultiplexers in order to perform channel source identification is not necessary. This leads to a relatively inexpensive technique of channel source identification that is useful in determining the connectivity of an NE in a DWDM system.

[0008] According to an aspect of the present invention there is provided an apparatus for communicating ancillary data in a wavelength division multiplexed system comprising: a modulator for modulating a sub-carrier frequency signal with the ancillary data; an intensity modulator for amplitude intensity modulating an optical data signal with the modulated sub-carrier frequency signal; a tap coupler for tapping a portion of the amplitude intensity modulated optical signal; an opto-electronic converter for converting the tapped portion of the optical signal to an electrical signal; and a detector for detecting the modulated sub-carrier frequency signal from the electrical signal, and for detecting the ancillary data from the modulated sub-carrier frequency signal.

[0009] According to another aspect of the present invention there is provided an encoder for communicating ancillary data in a wavelength division multiplexed system comprising: a modulator for modulating a sub-carrier frequency signal with the ancillary data; and an intensity modulator for amplitude intensity modulating an optical data signal with the modulated sub-carrier frequency signal.

[0010] According to another aspect of the present invention there is provided a decoder for extracting ancillary data from an optical data signal that has been amplitude intensity modulated by a modulated sub-carrier frequency signal that has been modulated by the ancillary data in a wavelength division multiplexed system, comprising: a tap coupler for tapping a portion of the modulated optical data signal; an opto-electronic converter for converting the tapped portion to an electrical signal; and a detector for detecting the modulated sub-carrier frequency signal from the electrical signal, and for detecting the ancillary data from the modulated sub-carrier frequency signal.

[0011] According to yet another aspect of the present invention there is provided a method of identifying channel sources in a wavelength division multiplexed system comprising the steps of: at a first node in the system, modulating a sub-carrier frequency signal with the ancillary data; at the first node, amplitude intensity modu-

lating an optical data signal with the modulated sub-carrier frequency signal; at the first node, transmitting the modulated optical data signal onto an optical fiber; at a second node in the system, tapping a portion of the modulated optical data signal from the optical fiber; at the second node, converting the tapped portion to an electrical signal; at the second node, detecting the modulated sub-carrier frequency signal from the electrical signal; and at the second node, detecting the ancillary data from the modulated sub-carrier frequency signal.

[0012] According to still another aspect of the present invention there is provided an amplitude intensity modulated optical signal for conveying ancillary data in a wavelength division multiplexed system comprising: pulse modulated light of a constant wavelength that has been modulated at a first bit rate by a first sequence of data symbols; and an amplitude intensity modulation of the pulse modulated light at a sub-carrier frequency that is less than the bit rate of the optical data signal divided by two and where the sub-carrier frequency has been modulated by ancillary data represented by a second sequence of data symbols, wherein the second sequence of data symbols has a bit rate that is at least eight orders of magnitude lower than the first bit rate.

[0013] According to still another aspect of the present invention there is provided an apparatus for communicating ancillary data in a wavelength division multiplexed system comprising: a data source for providing the ancillary data wherein the ancillary data includes channel source identifying information; and means for including the ancillary data in an optical data signal, wherein the optical data signal is amplitude intensity modulated by a signal that has been modulated by the ancillary data.

Brief Description of the Drawings

[0014] The invention will be better understood from the following description with reference to the drawings in which:

- FIG. 1 is a block diagram of a MON in accordance with an embodiment of the present invention;
- FIG. 2 is a block diagram of the Wavelength Insertion block of FIG. 1; and
- FIG. 3 is a block diagram of the Wavelength Detection block of FIG. 1.

Detailed Description

[0015] In FIG. 1 there is illustrated in a block diagram a MON 10 in accordance with an embodiment of the present invention. The MON 10 includes optical transmission equipment at a first site 20, at a second site 40, and at a third site 50. The equipment at the first site 20 includes a 2R transceiver 22, a 3:1 multiplexor 24 coupled to the transceiver 22 via an optical fiber 14, and an 11:1 multiplexor 26 coupled to the multiplexor 24 via an

optical fiber 16. The transceiver 22 is equipped with Wavelength Insertion apparatus 28.

[0016] In operation, an optical data signal s1 is input to the transceiver 22 via an optical fiber 12. The Wavelength Insertion apparatus 28 inserts the Wavelength into the signal s1, and a modulated optical data signal s2 is output on the optical fiber 14. The multiplexor 24 multiplexes the signal s2 with two other signals (not shown), which are similar to the signal s2 in format but are of different channel wavelengths, and outputs a multiplexed signal s3 onto the optical fiber 16. The multiplexor 26 multiplexes the signal s3 with ten other multiplexed signals (not shown), which are similar to the multiplexed signal s3 in format but are again of different channel wavelengths, then outputs a multiplexed signal s4 onto the optical fiber 18. Consequently, the multiplex signal s4 is composed of thirty-three signals, each signal of a different channel wavelength, and the Wavelength of each channel uniquely identifying its respective channel source.

[0017] The third site 50 includes an optical add drop multiplexor (OADM) 52. The OADM 52 is connected to the multiplexor 26 of the first site 20 via the optical fiber 18 and to the second site 40 via an optical fiber 38. The OADM 52 is capable of extracting, or dropping, channels from the signal s4. Further, the OADM 52 can add channels in the place of dropped channels, or it can simply copy information carried by any of the channels and thereby allow the signal s4 to effectively pass through the OADM 52. For simplicity, FIG. 1 shows the signal s4 passing through the OADM 52.

[0018] The second site 40 comprises a 1:11 demultiplexor 42 connected to the third site 50 via the optical fiber 38, a 1:3 demultiplexor 44 connected to the demultiplexor 42 via an optical fiber 36, and a 2R transceiver 46 connected to the demultiplexor 44 via an optical fiber 34. The transceiver 46 is equipped with Wavelength detection apparatus 48a. The demultiplexors 42 and 44 are also shown equipped with Wavelength detection apparatus 48b and 48c, respectively.

[0019] In operation, the multiplexed signal s4 is input to the demultiplexor 42 on the optical fiber 38. The signal s3 is output from the demultiplexor 42 on the optical fiber 36 and input to the demultiplexor 44. The modulated optical data signal s2 is output from the demultiplexor 44 on the optical fiber 34 and input to the transceiver 46. The Wavelength detection apparatus 48a, 48b, and 48c can be used in order to detect the Wavelengths on their respective input signals s2, s3, and s4, and thereby to determine wavelength source information of the channels. The transceiver 46 outputs an optical data signal s1' onto an optical fiber 32. The signal s1' includes the information contained in the signal s1 and the Wavelength of the signal s2.

[0020] It should be noted, that there would be a plurality of transceivers 28 and 46 at the first and second sites, respectively, however these transceivers have been omitted for clarity. Further, it should be noted that the Wavelength detection apparatus could be located in any

of the NEs 22, 24, 26, 52, 42, 44, and 46 shown in FIG. 1. This would allow each NE to determine its connectivity to the network by determining the wavelength source information from the Wavelengths of the channels that it is receiving. In addition, a piece of equipment for managing the network, often referred to as a network manager, which is in communication with each NE in the network, could determine the connectivity of the network from the wavelength source information of the channels that each NE is receiving.

[0021] In FIG. 2 there is illustrated in a block diagram the Wavelength insertion apparatus 28 of FIG. 1. The Wavelength insertion apparatus 28 includes a Wavelength data source 74, a Wavelength modulator 70 coupled to the Wavelength data source 74 via a link 73 and having an input for a sub-carrier frequency signal of frequency f_1 , and an intensity modulator 72 coupled to the Wavelength modulator 70 via a link 75. An optical fiber 71 is connected to the input of the intensity modulator 72, and at its output there is connected an optical fiber 77. A network manager 100 is shown communicatively coupled to the Wavelength data source 74 via a link 102.

[0022] In operation, ancillary data to be carried by the Wavelength is provided by the Wavelength data source 74, and optionally the network manager 100. The ancillary data includes channel source identification information such as: IP address of the source, physical location of the source, working or protection channel identification, payload format and bit rate, and other such information as dictated by future requirements. The ancillary data is provided to the Wavelength modulator 70. The Wavelength modulator 70 modulates the sub-carrier frequency signal of frequency f_1 with the ancillary data at a bit rate that is at least eight orders of magnitude (10^8) lower than the bit rate of the optical data signal s_1 . The sub-carrier frequency signal is amplitude modulated by the data to a given modulation depth m . The sub-carrier frequency signal has a frequency f_1 that is less than the bit rate of the optical data signal s_1 divided by two. That is, the sub-carrier frequency signal is an in-band sub-carrier with respect to the optical data signal s_1 . The resultant signal $mw(t)$ is input to the intensity modulator 72 via the link 75. The optical data signal s_1 , which can be represented by $(1 + d(t))P_{avg}$, where $d(t)$ is the time varying data and P_{avg} represents the average optical power, is input to the intensity modulator 72 via the optical fiber 71. The optical data signal s_1 is intensity amplitude modulated according to the signal $mw(t)$ by the intensity modulator 72. The resulting modulated optical data signal s_2 , which can be represented by $(1 + wm(t))(1 + d(t))P_{avg}$, is output on the optical fiber 77. Thus, the signal s_2 includes data of the type described earlier, the data being carried by the Wavelength. Typically, the data would have a bit rate in the range of one to ten bits per second, and would be repeated over time.

[0023] It should be noted, that while amplitude modulation of a sub-carrier by the ancillary data to be communicated has been described, other modulation for-

mat that would provide orthogonal Wavelengths are possible. These formats include such formats as: frequency or phase modulation of a sub-carrier, frequency or phase shift keying of a sub-carrier, code division multiple access (CDMA), frequency division multiple access (FDMA), and other formats known in the art. Furthermore, the intensity modulator 72 for modulating the optical data signal s_1 at a SONET transceiver could be an optical attenuator or a circuit for controlling laser bias current of the transceiver. In addition, the Wavelength is controlled to a target minimum modulation depth that both minimizes any undesirable effects that the modulation imposes on the optical data signal s_1 and allows the Wavelength to be reliably detected at optical multiplexed interfaces in the network.

[0024] In FIG. 3 there is illustrated in a block diagram the Wavelength detection apparatus 48a of FIG. 1. The Wavelength detection apparatus comprises a tap coupler 82, a PIN photo detector 84 coupled to the tap coupler 82 via an optical fiber 85, an electrical amplifier 86 connected to the PIN photo detector 84 via a link 87, a Wavelength Detector 80 connected to the amplifier 86 via a link 89 and having input signals of sub-carrier frequencies f_1 to f_n . The network manager 100 is shown communicatively coupled to the Wavelength detector 80 via a link 104. The modulated optical data signal s_2 is input to the tap coupler 82 via an optical fiber 81, and the signal s_1 is passed through the tap coupler 82 and output on an optical fiber 83. The input signals of sub-carrier frequencies f_1 to f_n are provided by the transceiver 46, where n is the maximum number of channels carried by a signal in the network; in this case n is thirty-three. The sub-carrier frequencies f_1 to f_n could range from $f_1 = 20$ kHz to $f_n = 660$ kHz with an increment of 20 kHz between adjacent frequencies.

[0025] In operation, the modulated optical data signal s_2 is input to the tap coupler 82, and a portion s_2' of the modulated optical data signal s_2 is tapped and output on the fiber 85, while the remainder is output on the optical fiber 83. Typically, five percent of the optical power of the input signal is tapped by the tap coupler 82. The portion s_2' is input to the PIN photo detector 84 that converts the portion s_2' to an electrical signal se_2 . This signal has a low power level and is typically noisy. However, because of the low data rate of each Wavelength, which would generally be in the range of 1-10 bps, the data carried by each Wavelength can be reliably received despite the noise present on the electrical signal se_2 . The electrical signal se_2 is input to the amplifier 86 that outputs an amplified electrical signal se_2' . This amplified electrical signal se_2' is input to the Wavelength detector 80, and the Wavelengths carried on sub-carrier frequency signals of frequencies f_1 to f_n are detected. This detection can be done in a number of ways that are known in the art. One technique would be to provide a high Q filter for each sub-carrier frequency signal, with each filter having a center frequency that is equal to the frequency of the respective sub-carrier frequency signal. The respective

amplitude modulated WavelD could then be envelope detected at the output of each filter using a simple envelope detector. The data detected from each WavelD would be available to the NE equipped with the WavelD detection apparatus 48a and may be sent to the Network Manager 100 over the link 104. This data includes information that identifies the wavelength source of each channel, and therefore, the data can be used to determine the connectivity of the NE to the network.

[0026] It should be noted, that although the above discussed the detection of WavelDs carried by amplitude modulated sub-carrier frequency signals, other techniques of WavelD detection are possible, and such techniques would need to be compatible with the WavelD modulation format used. Examples of such formats were given earlier in connection with the WavelD insertion apparatus 28. A particularly flexible WavelD detector 80 would include a high speed analog to digital converter (A/D) and a digital signal processor (DSP). This type of WavelD detector would have the flexibility of detecting different types of low bit rate WavelD modulation formats, and the detector would have enough processing power to decode in parallel the information contained in the WavelDs.

[0027] The WavelDs could be detected at any optical NE where there is a benefit in doing so. Examples include: at the output of optical multiplexors and at the input of optical demultiplexors for determining the connectivity to the network of each, and at the input of optical amplifiers for associating a set of transmitters to a chain of optical amplifiers, which is useful in equalizing the optical power of the channels.

[0028] It should be noted that a WavelD is not limited to carrying only channel wavelength source and related information. Any ancillary data for which the bit rate of the WavelD is suitable could be carried over the WavelD.

[0029] Numerous modifications, variations, and adaptations may be made to the particular embodiments of the invention described above without departing from the scope of the invention, which is defined in the claims.

Claims

1. An apparatus for communicating ancillary data in a wavelength division multiplexed system comprising:

a modulator for modulating a sub-carrier frequency signal with the ancillary data;
 an intensity modulator for amplitude intensity modulating an optical data signal with the modulated sub-carrier frequency signal;
 a tap coupler for tapping a portion of the amplitude intensity modulated optical signal;
 an opto-electronic convertor for converting the tapped portion of the optical signal to an elec-

trical signal; and
 a detector for detecting the modulated sub-carrier frequency signal from the electrical signal, and for detecting the ancillary data from the modulated sub-carrier frequency signal.

2. An apparatus as claimed in claim 1; wherein the modulator is for modulating the sub-carrier frequency signal with the ancillary data at a bit rate that is at least eight orders of magnitude lower than the bit rate of the optical data signal.
3. An apparatus as claimed in claim 2, wherein the frequency of the sub-carrier frequency signal is less than the bit rate of the optical data signal divided by two.
4. An apparatus as claimed in claim 3, wherein the ancillary data includes channel source identification information;
5. An apparatus as claimed in claim 4, wherein the modulator is an amplitude modulator.
6. An apparatus as claimed in any of claims 1 to 5, wherein the ancillary data includes an Internet protocol address of the channel source.
7. An apparatus as claimed in any of claims 1 to 5, wherein the ancillary data includes a physical location identifier of the channel source.
8. An apparatus as claimed in any of claims 1 to 5, wherein the ancillary data includes a working or protection channel source identifier.
9. An apparatus as claimed in any of claims 1 to 5, wherein the ancillary data includes a payload format identifier.
10. An apparatus as claimed in any of claims 1 to 5, wherein the ancillary data includes a payload bit rate identifier.
11. An encoder for communicating ancillary data in a wavelength division multiplexed system comprising:
 a modulator for modulating a sub-carrier frequency signal with the ancillary data; and
 an intensity modulator for amplitude intensity modulating an optical data signal with the modulated sub-carrier frequency signal.
12. An encoder as claimed in claim 11, wherein the modulator is for modulating the sub-carrier frequency signal with the ancillary data at a bit rate that is at least eight orders of magnitude lower than the bit

rate of the optical data signal.

13. An encoder as claimed in claim 12, wherein the bit rate of the modulated sub-carrier frequency signal is less than the bit rate of the optical data signal divided by two.
14. An encoder as claimed in claim 13, wherein the ancillary data includes channel source identification information.
15. An encoder as claimed in claim 14, wherein the modulator is an amplitude modulator.
16. An encoder as claimed in any of claims 11 to 15, wherein the ancillary data includes an Internet protocol address of a channel wavelength source.
17. An encoder as claimed in any of claims 11 to 15, wherein the ancillary data includes a physical location identifier of a channel source.
18. An encoder as claimed in any of claims 11 to 15, wherein the ancillary data includes a working or protection channel source identifier.
19. An encoder as claimed in any of claims 11 to 15, wherein the ancillary data includes a payload format identifier.
20. An encoder as claimed in any of claims 11 to 15, wherein the ancillary data includes a payload bit rate identifier.
21. A decoder for extracting ancillary data from an optical data signal that has been amplitude intensity modulated by a modulated sub-carrier frequency signal that has been modulated by the ancillary data in a wavelength division multiplexed system, comprising:
 - a tap coupler for tapping a portion of the modulated optical data signal;
 - an opto-electronic convertor for converting the tapped portion to an electrical signal; and
 - a detector for detecting the modulated sub-carrier frequency signal from the electrical signal, and for detecting the ancillary data from the modulated sub-carrier frequency signal.
22. A decoder as claimed in claim 21, wherein the decoder is for extracting ancillary data that is provided at a bit rate that is at least eight orders of magnitude lower than the bit rate of the optical data signal.
23. A decoder as claimed in claim 22, wherein the bit rate of the modulated sub-carrier frequency signal is less than the bit rate of the optical data signal divided by two.
24. A decoder as claimed in claim 23, wherein the ancillary data includes channel source identification information.
25. A decoder as claimed in claim 24, wherein the detector is for detecting the ancillary data from an amplitude modulated sub-carrier frequency signal.
26. A decoder as claimed in any of claims 21 to 25, wherein the ancillary data includes an Internet protocol address of a channel source.
27. A decoder as claimed in any of claims 21 to 25, wherein the ancillary data includes a physical location identifier of a channel source.
28. A decoder as claimed in any of claims 21 to 25, wherein the ancillary data includes a working or protection channel source identifier.
29. A decoder as claimed in any of claims 21 to 25, wherein the ancillary data includes a payload format identifier.
30. A decoder as claimed in any of claims 21 to 25, wherein the ancillary data includes a payload bit rate identifier.
31. A method of communicating ancillary data in a wavelength division multiplexed system comprising the steps of:
 - a) at a first node in the system, modulating a sub-carrier frequency signal with the ancillary data;
 - b) at the first node, amplitude intensity modulating an optical data signal with the modulated sub-carrier frequency signal;
 - c) at the first node, transmitting the modulated optical data signal onto an optical fiber;
 - d) at a second node in the system, tapping a portion of the modulated optical data signal from the optical fiber;
 - e) at the second node, converting the tapped portion to an electrical signal;
 - f) at the second node, detecting the modulated sub-carrier frequency signal from the electrical signal; and
 - g) at the second node, detecting the ancillary data from the modulated sub-carrier frequency signal.
32. A method as claimed in claim 31, wherein the step a) of modulating the sub-carrier frequency signal with the ancillary data is performed at a bit rate that is at least eight orders of magnitude lower than the

bit rate of the optical data signal.

formation.

33. A method as claimed in claim 32, wherein the step
a) of modulating the sub-carrier frequency signal is
performed on an electrical signal that has a frequency
that is less than the bit rate of the optical data
signal divided by two. 5
34. A method as claimed in claim 33, wherein the ancillary
data includes channel source identification
information. 10
35. A method as claimed in claim 34, wherein the step
a) of modulating the sub-carrier frequency signal is
performed by amplitude modulation. 15
36. A method as claimed in any of claims 31 to 35,
wherein the ancillary data includes an Internet protocol
address of a channel source. 20
37. A method as claimed in any of claims 31 to 35,
wherein the ancillary data includes a physical location
identifier of a channel source. 25
38. A method as claimed in any of claims 31 to 35,
wherein the ancillary data includes a working or protection
channel source identifier. 30
39. A method as claimed in any of claims 31 to 35,
wherein the ancillary data includes a payload format
identifier. 35
40. A method as claimed in any of claims 31 to 35,
wherein the ancillary data includes a payload bit
rate identifier. 40
41. An amplitude intensity modulated optical signal for
conveying ancillary data in a wavelength division
multiplexed system comprising: 45
 - pulse modulated light of a constant wavelength
that has been modulated at a first bit rate by a
first sequence of data symbols; and
 - an amplitude intensity modulation of the pulse
modulated light at a sub-carrier frequency that
is less than the bit rate of the optical data signal
divided by two and where the sub-carrier frequency
has been modulated by ancillary data represented by a second
sequence of data symbols, wherein the second sequence of data
symbols has a bit rate that is at least eight orders
of magnitude lower than the first bit rate. 50
42. A signal as claimed in claim 41, wherein the sub-
carrier frequency is amplitude modulated. 55
43. A signal as claimed in claim 42, wherein the ancillary
data includes channel source identification information.
44. A signal as claimed in any of claims 41 to 43, wherein
the ancillary data includes an Internet protocol
address of a channel source.
45. A signal as claimed in any of claims 41 to 43, wherein
the ancillary data includes a physical location
identifier of a channel source.
46. A signal as claimed in any of claims 41 to 43, wherein
the ancillary data includes a working or protection
channel source identifier.
47. A signal as claimed in any of claims 41 to 43, wherein
the ancillary data includes a payload format identifier.
48. A signal as claimed in any of claims 41 to 43, wherein
the ancillary data includes a payload bit rate identifier.
49. An apparatus for communicating ancillary data in a
wavelength division multiplexed system comprising:
 - a data source for providing the ancillary data
wherein the ancillary data includes channel
source identifying information; and
 - means for including the ancillary data in an optical
data signal, wherein the optical data signal
is amplitude intensity modulated by a signal
that has been modulated by the ancillary data.

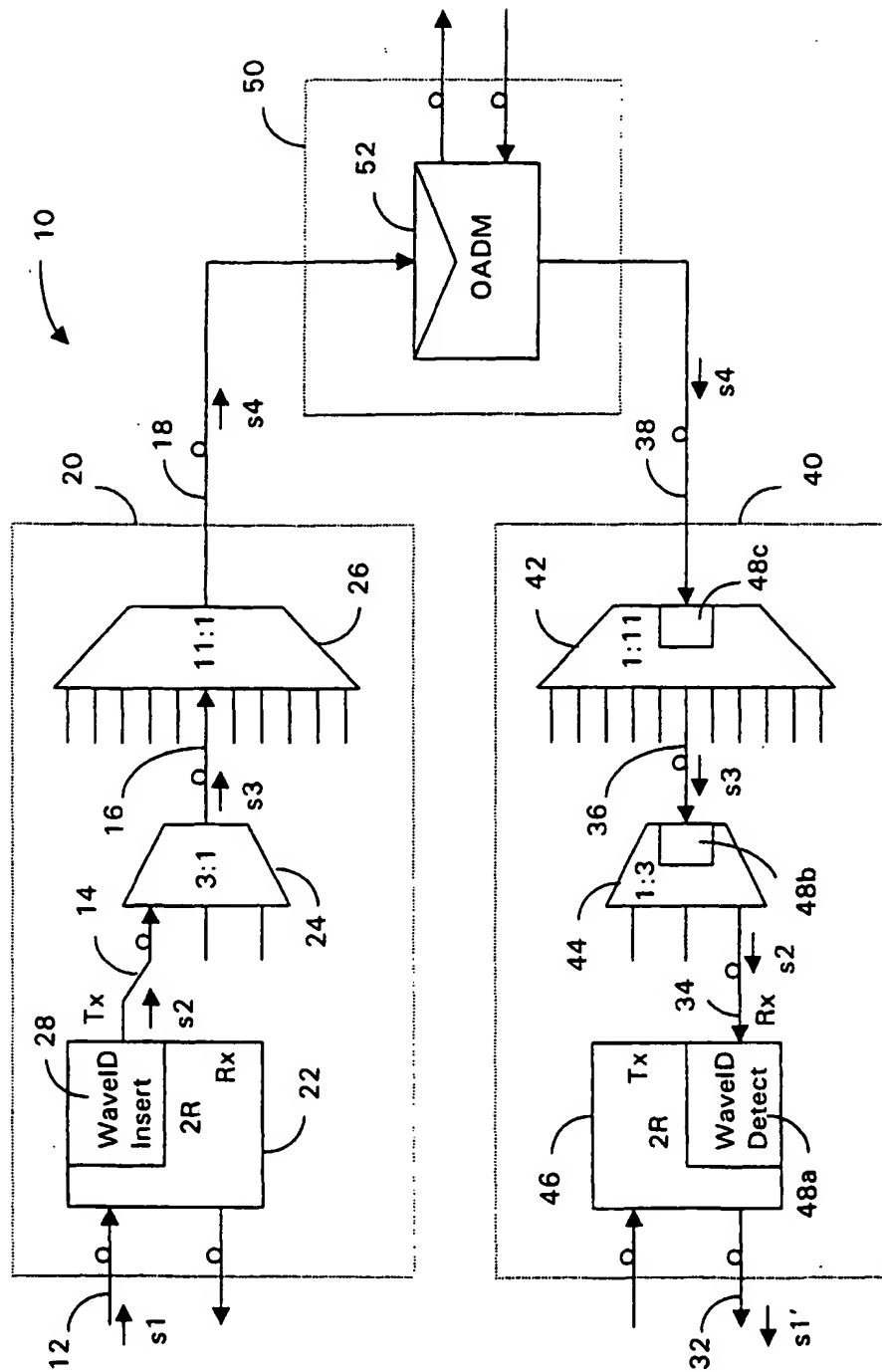


FIG.1

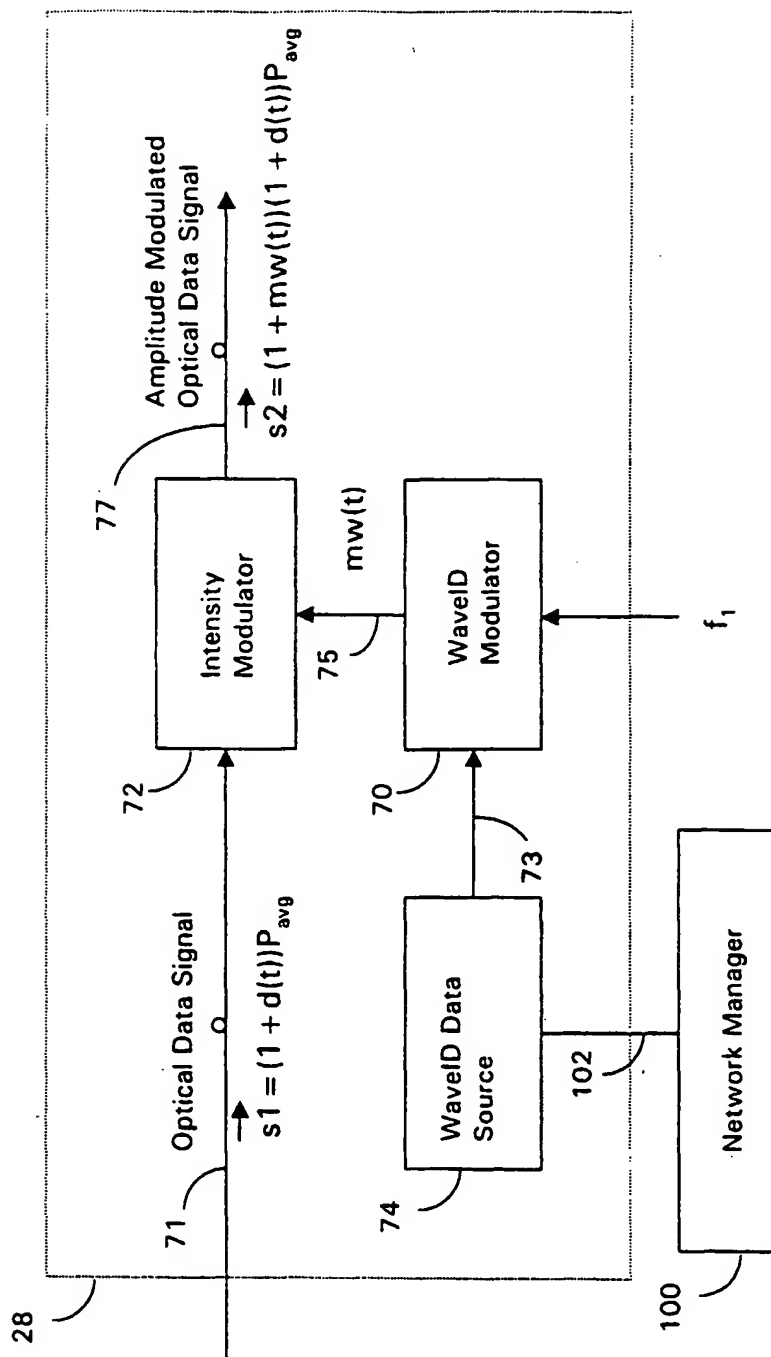


FIG. 2

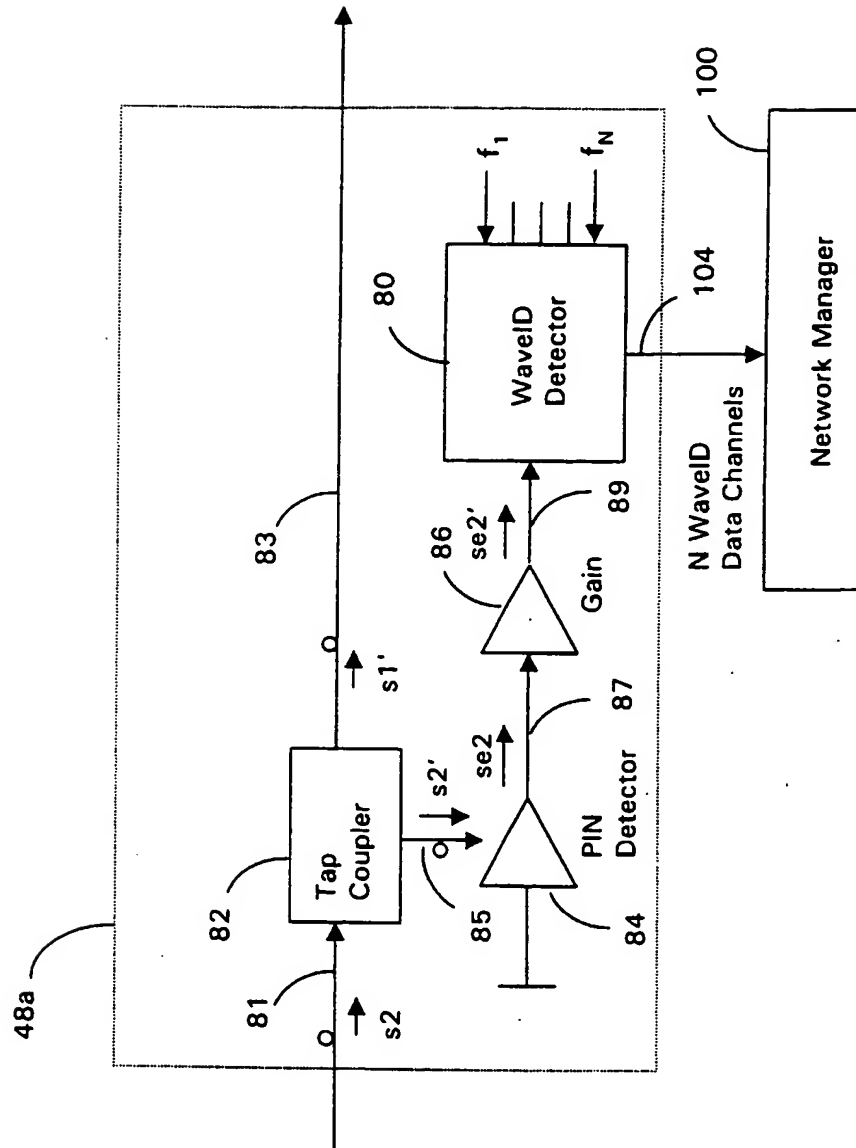


FIG. 3

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